CLAIMS

1. In a process for securing a bearing on a spindle, the bearing having inner and outer races with rolling elements interposed therebetween, the inner race being received on the spindle for rotation therewith and the spindle having a deformable spindle end portion that extends beyond the inner race, the spindle end portion being engaged with a forming tool that rotates about a tool axis that is inclined to the spindle axis to gradually deform the spindle end portion and create a formed end that lies against an end face of the inner bearing race, characterized in that during the forming operation the spindle and inner race are rotated while the outer race is maintained essentially stationary.

2. The process of claim 1 wherein the inclination angle of the tool axis is variable.

3. The process of any of claims 1 or 2 wherein during the forming operation both the forming tool and the spindle are rotated in the same direction.

4. The process of claim 3 wherein the forming tool is rotated at a lesser velocity than the spindle.

5. The process of any of claims 1-4 wherein the spindle and the forming too are engaged with one another by moving at least one of the spindle and the forming tool toward the other at a first velocity during the initial and intermediate stages of the forming operation an l

at a second velocity that is slower than the first velocity in the final stages of the forming operation during which the formed end is worked against the end face of the inner bearing race.

6. The process of any of claims 1-5 wherein during the forming operation th spindle end portion and the forming tool engage one another with a force that does not exceed 1 tonnes.

7. The process of claim 6 wherein the magnitude of the force is monitored.

8. The process of claim 6 wherein the force is between 6-8 tonnes.

9. The process of any of claims 1-8 wherein the spindle end portion and th forming tool are engaged with one another by linearly moving the spindle axially toward the rotating forming tool which remains in an essentially fixed position.

10. In an apparatus for securing a bearing on a spindle, the bearing having inner and outer races with rolling elements interposed therebetween, the inner bearing race be ng received on the spindle for rotation therewith and the spindle having a deformable spindle en portion that extends beyond the inner race, the apparatus comprising:

a rotatable spindle support that supports the spindle for rotation with the spin le support about the spindle axis;

a restraining device that restrains the outer bearing race against rotation with the spindle and the inner bearing race;

a forming tool rotatable about a tool axis that is inclined to the axis of the spindle; and

at least one of the spindle support and the forming tool being linearly movable toward the other to engage the forming tool with the deformable spindle end portion and create a formed end that lies against an end face of the inner bearing race.

11. The apparatus of claim 10 wherein the inclination angle of the tool axis is variable.

12. The apparatus of any of claims 10 or 11 wherein the forming tool and the spindle support are rotated in the same direction.

13. The apparatus of claim 12 wherein the forming tool is rotated at a lesser velocity than the spindle.

14. The apparatus of any of claims 10-13 wherein at least one of the forming tool and the spindle support is movable toward the other at a first velocity during the initial and intermediate stages of the forming operation and at a second velocity that is slower than the first velocity in the final stages of the forming operation during which the formed end is worked against the end face of the inner bearing ring.

15. The apparatus of any of claims 10-14 including a force monitoring device that monitors the magnitude of the force with which the spindle and forming tool engage one another.

16. The apparatus of any of claims 10-15 including a ram that moves the spindle support linearly toward the forming tool while the forming tool remains in an essentially fixed position.

17. The apparatus of claim 16 wherein the force of engagement between the spindle and the forming tool that the ram provides does not exceed 12 tonnes.

18. The apparatus of claim 16 wherein the force of engagement between the spindle and the forming tool that the ram provides does not exceed 8 tonnes.

19. The apparatus of claim 16 wherein the ram provides a force of engagement between the spindle and forming tool that is between 6-8 tonnes.

20. An assembly comprising: a first component having an opening, a second component having an axial bore and an end portion received in and extending through the opening, wherein the end portion is radially deformed with respect to the axis to create a formed end that wraps around the first component, wherein the formed end includes a curved outside end surface that merges with a flat outside end surface, perpendicular to the axis, which merges into a

first beveled surface, formed at an oblique angle to the axis, which merges into a second beveled surface, formed at a steeper angle to the axis than the first beveled surface, which merges into the axial bore.

21. In a process for securing a component on a spindle, the component having an opening in which the spindle is received for rotation of the component with the spindle, the spindle having a deformable spindle end portion extending beyond the opening, the spindle end portion being engaged with a forming tool that rotates about a tool axis that is inclined to the spindle axis to gradually deform the spindle end portion and create a formed end that lies against an end face of the component to secure the component on the spindle, characterized in that during the forming operation both the forming tool and the spindle are rotated in the same direction.

22. The process of claim 21 wherein the forming tool is rotated at a lesser velocity than the spindle.

23. The process of any of claims 21 or 22 wherein the inclination angle of the tool axis is variable.

24. The process of any of claims 21-23 wherein the spindle is engaged with the forming tool by moving at least one of the spindle and the forming tool toward the other at a first velocity during the initial and intermediate stages of the forming operation and at a second

velocity that is slower than the first velocity in the final stages of the forming operation during which the formed end is worked against the end face of the components.

25. The process of any of claims 21-24 wherein during the forming operation the spindle end portion and the forming tool engage one another with a force that does not exceed 12 tonnes.

26. The process of claim 25 wherein the magnitude of the force is monitored.

27. The process of claim 25 wherein the force is between 6-8 tonnes.

28. The process of any of claims 21-27 wherein the spindle end portion and the forming tool are engaged with one another by linearly moving the rotating spindle axially toward the rotating forming tool which remains in an essentially fixed position.

29. In a process for securing a component on a spindle, the component having an opening in which the spindle is received for rotation of the component with the spindle, the spindle having a deformable spindle end portion extending beyond the opening, the spindle end portion being engaged with a forming tool that rotates about a tool axis that is inclined to the spindle axis to gradually deform the spindle end portion and create a formed end that lies against an end face of the component to secure the component on the spindle, characterized in that

during the forming operation the forming tool and the spindle are brought together with a force that is not greater than 12 tonnes.

30. The process of claim 29 wherein the force of engagement between the forming tool and the spindle end portion is not greater than 8 tonnes.

31. The process of claim 30 wherein the force of engagement between the forming tool and the spindle end portion is between 6-8 tonnes.

32. The process of any of claims 29-31 wherein the magnitude of the force of engagement between the forming tool and the spindle end portion is monitored.

33. The process of any of claims 29-32 wherein the spindle end portion and the forming tool are engaged with one another by moving at least one of the spindle and the forming tool toward the other at a first velocity during the initial and intermediate stages of the forming operation and at a second velocity that is slower than the first velocity in the final stages of the forming operation during which the formed end is worked against the end face of the component.

34. The process of any of claims 29-33 wherein the spindle end portion and the forming tool are engaged with one another by moving the spindle axially toward the rotating forming tool which remains in an essentially fixed position

35. The process of any of claims 29-34 wherein during the forming operation the spindle is rotated about its axis in the same rotational direction as the forming tool.

36. In a process for securing a component on a spindle, the component having an opening in which the spindle is received for rotation of the component with the spindle, the spindle having a deformable spindle end portion extending beyond the opening, the spindle end portion being engaged with a forming tool that rotates about a tool axis that is inclined to the spindle axis to gradually deform the spindle end portion and create a formed end that lies against an end face of the component to secure the component on the spindle, characterized in that at least one of the forming tool and the spindle is moved toward the other at a first velocity during the initial and intermediate stages of the forming operation and at a second velocity that is slower than the first velocity in the final stages of the forming operation during which the formed end is worked against the end face of the component.

37. The process of claim 36 wherein during the forming operation the spindle is rotated about its axis in the same direction as the forming tool.

38. The process of any of claims 36 or 37 wherein the spindle end portion is engaged with the forming tool by linearly moving the spindle axially toward the forming tool which remains in an essentially fixed position.

39. Apparatus for securing a component on a spindle, the component having an opening in which the spindle is received for rotation of the component with the spindle, the spindle having a deformable end portion extending beyond the opening, the apparatus comprising:

a rotatable spindle support that supports the spindle and rotates about the spindle axis;

a forming tool that is rotatably driven about a tool axis that is inclined to the spindle axis;

a spindle support rotating device that rotates the spindle support in the same rotational direction as the forming tool; and

a linear actuator that linearly moves at least one of the spindle support and the forming tool toward the other to engage the spindle end portion with the forming tool to gradually deform the spindle end portion and create a formed end that lies against an end face of the component.

40. The apparatus of claim 39 wherein the linear actuator linearly moves at least one of the spindle support and the forming tool at a first velocity during the initial and intermediate stages of the forming operation and at a second velocity that is slower than the first velocity in the final stages of the forming operation during which the formed end is worked against the end face of the component.

41. The apparatus of any of claims 39 or 40 including a forming tool adjusting device for adjusting the inclination angle of the tool axis.

42. The apparatus of any of claims 39-41 wherein the linear actuator linearly moves the spindle support toward the forming tool which remains in an essentially fixed position.

43. The apparatus of any of claims 39-42 including a force monitoring device that monitors the magnitude of the force with which the spindle and forming tool engage one another.

44. The apparatus of any of claims 39-43 wherein the linear actuator provides a force of engagement between the spindle end portion and the forming tool that does not exceed 12 tonnes.

45. The apparatus of any of claims 39-43 wherein the linear actuator provides a force of engagement between the spindle end portion and the forming tool that does not exceed 8 tonnes.

46. The apparatus of any of claims 39-43 wherein the linear actuator provides a force of engagement between the spindle end portion and the forming tool that is between 6-8 tonnes.

47. In an assembly wherein a component is secured on a spindle by a deformed spindle end portion, the spindle having an outer cylindrical spindle surface and an internal axial cylindrical spindle bore, the component having an opening in which the spindle is received for rotation of the component with the spindle, the spindle having a formed end that is outwardly deformed into engagement with an end face of the component to secure the component on the spindle, the formed end extending outwardly at 90° to the spindle axis, the formed end having an inside end surface that merges into the outer cylindrical spindle surface at an inside intersection, the formed end having an axially facing outside end surface that merges into the surface of the cylindrical spindle bore at an outside intersection, characterized in that the outside intersection is not a smooth curve and cuts across the spindle bore surface and the axially facing outside end surface of the formed end closer to the inside intersection to provide the formed end with a reduced thickness in a direction diagonally across the inside and outside intersections.

48. The assembly of claim 47 wherein the outside intersection includes at least one beveled surface that extends at an oblique angle to the spindle axis and intersects at least one of the spindle bore surface and the axially facing outside end surface of the formed end.

49. The assembly of any of claims 47 or 48 wherein the formed end has a curved outside end surface that curves from said axially facing outside end surface toward said inside end surface.

50. The assembly of any of claims 47-49 wherein said axially facing outside end surface is flat and perpendicular to the spindle axis.

51. The assembly of any of claims 47-50 wherein said component is an inner bearing ring of a bearing assembly that includes an outer bearing ring and a plurality of rolling elements interposed between the inner and outer bearing rings, the formed end engaging the inner bearing ring without imparting excessive distortion thereto so that the maximum torque in the bearing is not greater than 40 in-lbs.

52. A spindle having an outer cylindrical surface and an axial bore with an inner cylindrical surface, the spindle having a deformable end portion that has a terminal end surface, and a steep tapered surface extending along a portion of the length of said deformable end portion from the terminal end surface toward the inner cylindrical surface.

53. The spindle of claim 52 wherein the deformable end portion has a radial thickness that is less than the radial thickness of the spindle between the inner and outer cylindrical surfaces, the deformable end portion having an outer cylindrical surface that is a continuation of the outer cylindrical surface on the spindle, and the deformable end portion having an inner surface that is spaced from the inner cylindrical surface of the spindle in a direction toward the outer cylindrical surface of the deformable end portion.

54. The spindle of claim 52 including a slightly tapered surface extending along a portion of the length of the deformable end portion from the steep tapered surface toward the inner cylindrical surface.

55. The spindle of claim 54 wherein the slightly tapered surface extends along a greater portion of the length of the deformable end portion than the steep tapered surface.

56. The spindle of claim 55 wherein the spindle has a spindle axis, the slightly tapered surface being inclined to the spindle axis at a smaller angle than the angle of inclination of the steep tapered surface to the spindle axis.

57. The spindle of claim 54 including a beveled surface extending from the inner cylindrical surface to intersection with the slightly tapered surface.

58. The spindle of claim 57 wherein the spindle has a spindle axis, the beveled surface being inclined to the spindle axis at a larger angle than the steep tapered surface, and the slightly tapered surface being inclined to the spindle axis an angle that is smaller than the inclination angles of both the beveled surface and the steep tapered surface.

59. The spindle of claim 52 wherein the terminal end surface of the deformable end portion is flat.

60. The spindle of claim 52 wherein the intersection between the terminal end surface and the steep tapered surface is rounded.